# DEVELOPING AN EFFECTIVE AND ACCEPTABLE SAFETY BELT REMINDER SYSTEM

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## ABSTRACT

Front-seat safety belt use in the United States (US) was 80 percent in June, 2004. This rate represents the highest ever for the US, but indicates that there is still a sizable minority of people who do not always use safety belts despite mandatory seat belt laws in all but one state. Changing the behavior of these people will require new and innovative countermeasures. Little research has systematically investigated the effectiveness, feasibility, and acceptance of vehicle-based countermeasures for promoting safety belt use. The purpose of this project was to promote safety belt use in the US by conducting research to develop an effective in-vehicle safety belt reminder system. Project activities included a nationwide survey of part-time safety belt users, development of potential safety belt reminder system ideas, and a series of focus groups with part-time safety belt users. The results indicated that the most effective and acceptable safety-belt reminder system concept was one that was adaptive; that is, one that changes its signal type and presentation modality depending on belt use behavior over some metric (time, distance, or speed). The study also assessed and developed an potential reminder system ideas for informing drivers about back-seat belt use.

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## INTRODUCTION

The single most effective technology for reducing or preventing injuries from a motor vehicle crash is the safety belt restraint system. This system, however, is only effective if it is used. The most recent nationwide survey of safety belt use in the United States (US), the National Occupant Protection Use Survey (NOPUS), estimated that 80 percent of front-outboard motor vehicle occupants use their safety belt (Glassbrenner, 2004). While this is the highest rate ever in the US, the rate is lower than many other developed countries (e.g., Boase, Jonah, & Dawson, 2004) and shows that a significant portion of US travelers do not use safety belts, even though belt use is mandated in all but one state.

For nearly 30 years, the US federal government and vehicle manufacturers have developed and implemented numerous technologies for promoting safety belt use, with varying degrees of success. In the 1970s, the federal government mandated two vehicle-based safety belt use promotion technologies. The first required vehicles manufactured after 1971 to have a continuous buzzer-light safety belt reminder when safety belts were not used (vehicles equipped with air bags were excluded; Robertson, 1975). Analysis of belt use before and after the buzzer-light systems were installed showed no statistical increase in safety belt use (Robertson & Haddon, 1974). The federal government then mandated that all new vehicles sold after August 15, 1973 be equipped with a safety-belt-ignition-interlock system that prevented the vehicle from starting if the driver and front-right passenger were not using safety belts (Buckley, 1975). Despite the fact that these interlock systems increased safety belt use by as much as 30 percentage points (see e.g., Robertson,1975), public opposition to them led Congress to rescind the legislation in 1975. The three main reasons cited for opposition to safety-belt-interlock system were: 1) problems with proper functioning of the system when no front-right passenger was present; 2) safety concerns associated with preventing drivers from rapidly starting a vehicle in the event of an emergency; and 3) the relative ease of disabling the ignition interlocks.

After 1975, the US federal government turned its attention to legislating safety belt use. In the 1980s, the federal government began to urge states to pass legislation that required the use of safety belts, with New York passing the first mandatory safety belt use law in 1984. While these laws were initially unpopular in many states, every state except New Hampshire has now passed a safety belt use law. There is clear evidence that these laws have been successful in increasing safety belt use (see e.g., Eby, Molnar, & Olk, 2000; Reinfurt, Campbell, Stewart, & Stutts, 1990; Ulmer, Preusser, & Preusser, 1994).

In the 1980s, the federal government required that vehicles have passive occupant protection systems, and manufacturers responded by developing the automatic belt systems in which the shoulder belt automatically positions itself after the driver starts the vehicle. Research has shown that automatic belt systems do increase safety belt use (Streff & Molnar, 1991). However, these systems were judged as being less effective than the 3-point safety belt and were not well liked by consumers. When the federal government clarified its definition of "passive occupant protection" to encompass air bags, automatic belts were largely eliminated from newly manufactured vehicles.

Recent attention has turned to the development of new in-vehicle technologies for increasing belt use (NHTSA, 2003; Transportation Research Board, TRB, 2003). One promising technology is the safety belt reminder system. Since 1975, all new vehicles in the US have been required to display a 4-8 second signal if the driver does not use the safety belt after starting the vehicle. Once the belt is fastened, the signal stops. This relatively benign reminder system is easily ignored. Therefore, further research is needed to develop more effective and acceptable in-vehicle technologies to promote safety belt use, such as safety belt reminder systems.

### *The Project*

The purpose of the project was to promote safety belt use in the US by gaining a better understanding of the effectiveness of current safety belt reminder systems as well as suggesting appropriate improvements. The project examined several aspects of vehicle-based safety belt use technologies. Two main research tasks were completed: a nationally-representative survey of part-time safety belt users and a series of focus groups with part-time safety belt users. A literature review was also performed. Results from this review appear throughout this document.

The project design was iterative in nature; that is, after each task, University of Michigan Transportation Research Institute (UMTRI) personnel met with sponsor representatives and we refined our thinking about the characteristics that would lead to effective and acceptable in-vehicle safety belt promotion technology. Combining information obtained from the literature review, UMTRI's background in occupant protection research, and the sponsor's expertise in developing in-vehicle safety technology, we developed a set of topics for the telephone survey and focus groups that we believed were relevant to the development of safety belt reminder systems. These topics included:

- The demographic trends of part-time safety belt users;
- Part-time safety belt users' attitudes toward belt use;
- Reasons for part-time belt use by seating position;
- Which types of system were thought be effective and acceptable to part-time users.

After detailed discussion with all parties on the project, we realized that the number of potential systems we could investigate was vast. The decision was made, therefore, to investigate *features* of potential systems rather than example systems per se. These features were:

- The type of signal;
- The signal presentation method;
- The signal recipient.

In addition, safety-belt-interlock systems have the potential to be effective in-vehicle technologies for promoting safety belt use. As discussed previously, safety-belt-*ignition* interlocks were mandated in the US until public dissatisfaction led to their repeal. Other vehicle systems could be interlocked with safety belt use, such as the heating/cooling or entertainment systems. Therefore, we investigated features of this potential technology in the project.

## METHODS

### *Nationwide Telephone Survey*

The objective of the telephone survey was to gather information from a nationally representative sample of part-time safety belt users about their nonuse of safety belts, the reasons for this behavior, and what it would take to get them to use their safety belts. For the purpose of this survey, a part-time safety belt user was defined as a person who, by self-report, had not used a safety belt on at least one occasion in the last year either as a driver or passenger (front or back seat) in a private car that had safety belts available. This included not using a safety belt for some portion of the trip, other than a few moments at the very beginning or the very end of the trip.

A telephone survey instrument was developed with a screener to identify part-time safety belt users and to collect basic demographic information from those who did not qualify as part-time users. Once part-time users were identified, they were asked about their safety belt nonuse by seating position, reasons for safety-belt non-use, the perceived usefulness and acceptability of a set of system features of in-vehicle safety belt promotion technologies. The three system features investigated in the survey were: the signal type; the ways in which the signal could be delivered; and the target occupant(s) for the signal. We also investigated, to some extent, acceptability and effectiveness of these features for the driver when he or she is not belted (driver-driver), for the driver when a passenger is not belted (driver-passenger); and for the passenger when he or she is not belted (passenger-passenger). Other survey topics included:

- How often respondent was driver and/or passenger;
- Questions about the last time respondent did not use safety belt;
- Questions about respondent's general safety belt nonuse as driver and as passenger;
- Questions to driver about belt use of his/her passengers;
- Demographics.

The telephone survey utilized a nationally representative random-digit-dial (RDD) sample design of households. The telephone interviews were conducted by a professional survey research firm using Computer Assisted Telephone Interviewing (CATI) from April 21 to June 25, 2003. In all, there were 1,100 completed interviews from part-time safety belt users. The final sample was weighted to reflect regional population distributions of the US.

To obtain the final sample of 1,100 part-time safety belt users, 21,670 telephone numbers were used. If not answered, a telephone number was tried up to six times. Of the 21,670 telephone numbers called, 8,557 yielded persons eligible for an interview; 6,613 resulted in an ineligible classification (not part-time safety-belt users, not age 18 or older, disconnected number, fax or data line, business number); and 6,500 numbers resulted in an unknown classification (no answer, answering machine, scheduled for call-back). Using standard definitions for the final disposition of samples for RDD telephone surveys (American Association for Public Opinion Research, 1998), the minimum response rate for this survey was 7.3 percent and the maximum response rate 12.9 percent.

### *Focus Groups*

Twelve focus groups were conducted in Michigan to collect qualitative data from part-time safety belt users on the potential effectiveness and public acceptance of various features of systems that could be placed in cars to remind or encourage people to buckle up. Discussions also focused on safety belt use in general, including reasons for using and not using belts. Six of the groups were conducted in Ann Arbor, an urban/suburban area, and six in Clare, a rural area of the state. Within each location, two groups each of 18-29 year olds, 30-64 year olds, and people 65 and older were conducted.

Part-time safety belt users (defined as those who reported nonuse at least some of the time) were recruited through advertisements in local newspapers, as well as postings at local businesses, academic institutions, and community organizations (e.g., senior centers). Potential participants were screened via telephone to ensure that they met eligibility criteria (age 18 and older, valid driver license, part-time safety belt user). Background information on participants was collected during the telephone screening process. Each selected participant was scheduled for a focus group session and sent written confirmation through regular mail or e-mail according to their preference. Reminder telephone calls were made the day before each session. A total of 97 participants were recruited, and 87 actually appeared at their session and participated in the focus group. Participants received an honorarium of $50 cash as an incentive to participate. Each session lasted about 2 hours.

Discussion during the groups was guided by a moderator using a uniform set of questions. Participants were also provided with worksheets on which to record some of their answers to facilitate discussion. During each session, focus group participants were shown a short computer demonstration of a sample safety belt reminder system and asked about their reactions. Participants were told that the system was made up of three levels, with each level being activated only when the driver or front seat passenger remained unbuckled. If someone were to unbuckle during the trip, the system would start over from the beginning.

- <u>Level 1</u> corresponded to the current US government requirement that cars display a 4 to 8 second signal if drivers do not put on their seat belt after starting the car. This is typically a flashing light on the dashboard with some type of sound signal. In the sample reminder system, it included a blinking light and a beeping signal that came on when the engine started and continued for 8 seconds.
- <u>Level 2</u> included a sound signal (delivered by a female voice, a male voice, a buzzer, or a beeping signal) that repeats three times with 8 seconds in between.
- <u>Level 3</u> included either a buzzer or beeping signal that stays on continuously for 45 seconds.

Each group was audio-taped and a project staff member was present at each session, in addition to the moderator, to take notes. After each group, a debriefing session was held to identify important themes that emerged from the discussion. Analysis of the focus group discussions was based on the debriefings of project staff conducted immediately after each focus group, a review of notes taken during the focus groups, and the audio tape recordings of the focus group sessions.

## RESULTS

### *Nationwide Telephone Survey*

#### Respondents

About 60 percent of respondents were female; education level was fairly well-distributed; a wide variety of ages was included; and about 40 percent of respondents had young children in their household. Approximately 84 percent of the part-time safety belt users drove a car almost every day, and almost all were passengers in a car at some time in the past year. Nearly 80 percent of respondents were passengers in the back seat at least a few times in the last year. Nearly 42 percent did not use a safety belt within the previous week. When asked about seating position the last time a belt was not used, about 40 percent reported being a driver, 21 percent were passengers in the front seat, and about 34 percent were passengers in the back seat.

#### Reasons for Nonuse of Belts

We analyzed the primary reasons people gave for part-time nonuse of safety belts. In the survey, people were asked to think back to the last they did not use a safety belt in the past year and report the main reason for their lack of use. Respondents gave a wide variety of responses to this open-ended question. We discovered, however, that all of the responses fell into six broad nonuse categories: *cognitive/personal* (e.g., forgetting or not in habit); *comfort* (e.g., too big for belt or belt does not fit correctly), *convenience* (e.g., belt hard to reach), *low perceived risk* (e.g., only driving a short distance or not driving on public road), *social* (e.g., others not wearing belt), and *vehicle* (e.g., no belt in vehicle).

Figure 1 shows the percent of respondents in each category as a function of seating position. The most commonly cited reason for nonuse involved perceived risk, followed by cognitive/personal reasons. Comfort and convenience were also commonly-cited factors. Comparing reasons by seating position showed that risk was much more commonly cited by drivers than occupants in other seating positions; cognitive/personal reasons were more commonly cited for front-seat occupants than those in the back-seat; both comfort and convenience were more important for back-seat passengers than for the driver; and vehicle-based reasons were much more common for back-seat passengers.

Because so few respondents indicated that their lack of belt use resulted from social factors, this classification was excluded from further analyses. In addition, the vehicle-based reasons could not be addressed through any type in in-vehicle safety belt promotion technology; that is, if the belt is missing or the buckle is broken, a vehicle occupant cannot use

**Figure 1: Main Reason for Not Wearing Belt Last Time by Seating Location**

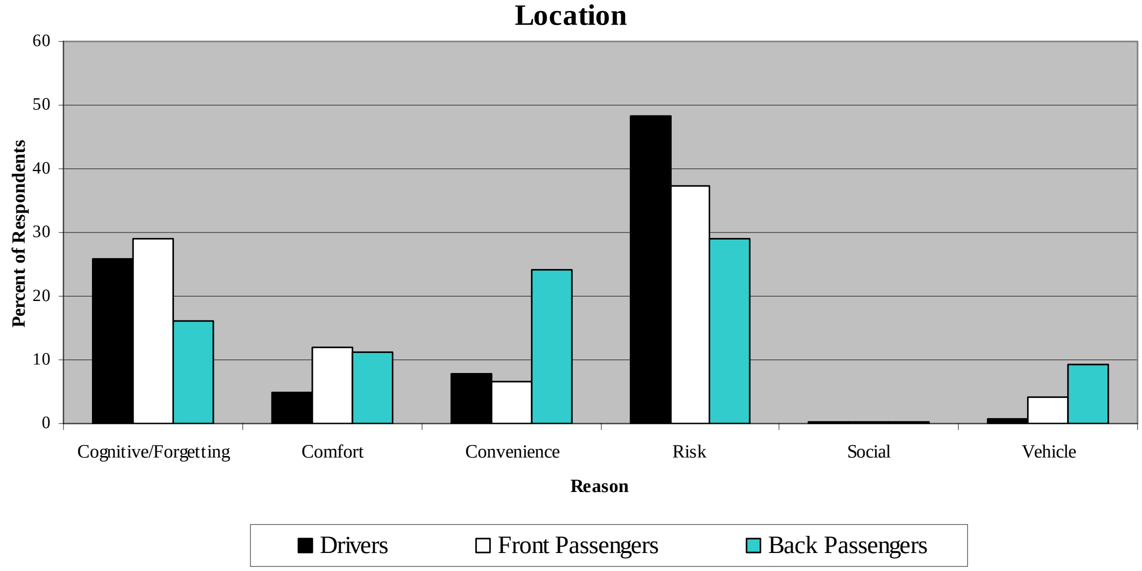
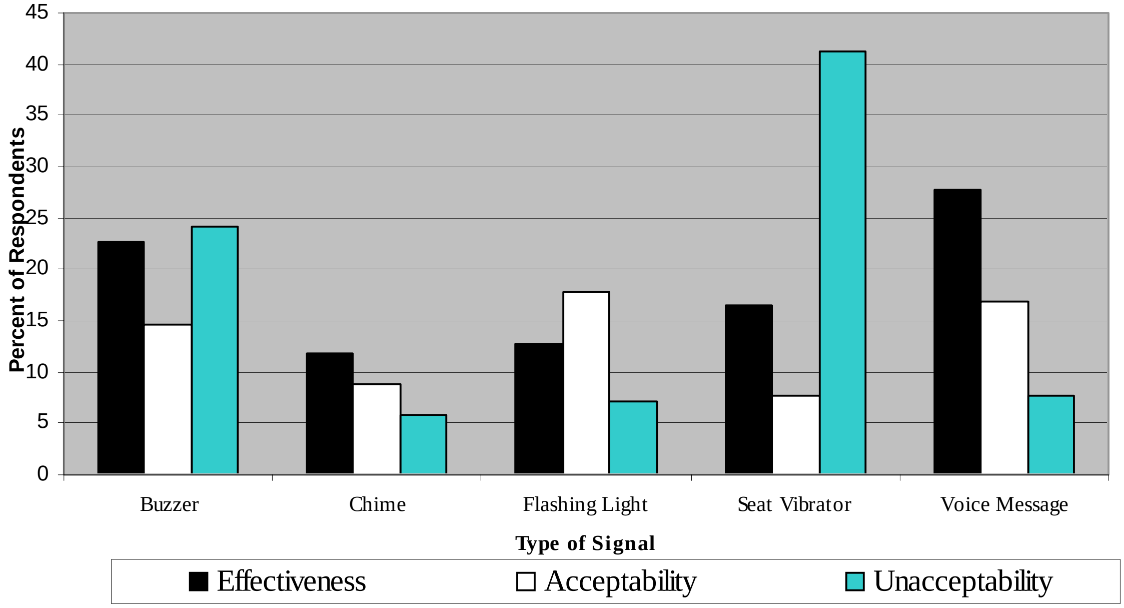


**Figure 2: System Signal Preferences as a Driver Cognitive/Personal Group**




the belt regardless of system effectiveness. Therefore, the vehicle-based classification was also excluded from further analyses. The classifications of comfort and convenience are not directly related to the development of effective in-vehicle belt promotion technologies as these factors are best addressed through human factors and ergonomic improvements to the vehicle interior. However, since these classifications were representative of many respondents and were of interest to the project team and sponsor, we combined them and addressed them separately from the in-vehicle belt promotion technology analyses.

## Comfort and Convenience

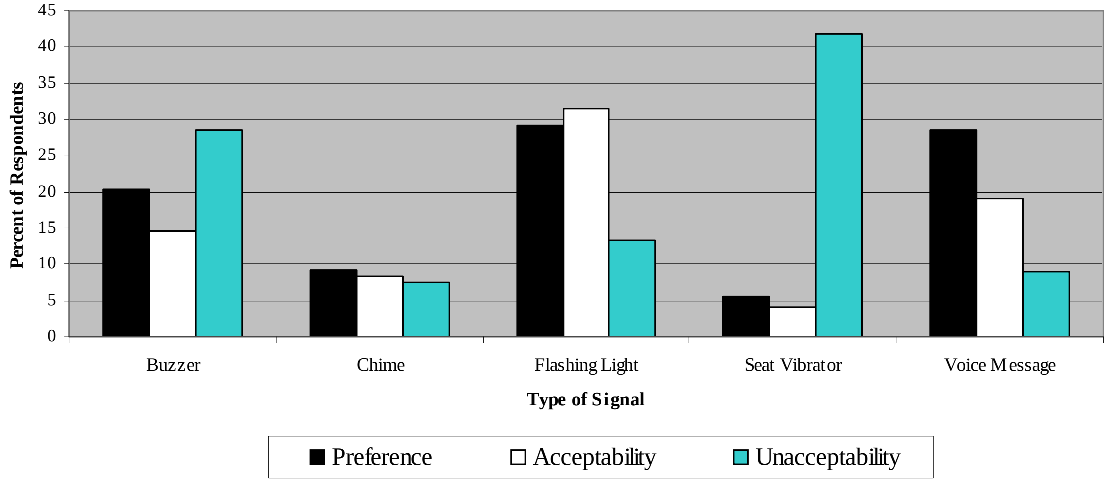
Survey results indicated that about 9 percent of respondents cited comfort and 13 percent cited convenience as the primary reason for nonuse of safety belts. As these classifications do not relate to the development of effective in-vehicle technology to promote belt use, the nationwide survey did not explore the dimensions of comfort and convenience in depth. A literature review on the topic, however, showed the following general results (Eby et al., 2004):

- Discomfort is a factor especially for shorter people (belt cuts into neck or clavicle);
- People who say they are not in the habit of buckling up are more likely to say belts are restricting and uncomfortable;
- Discomfort is more likely to be mentioned during winter and with heavier, bulkier clothing or coats;
- More complaints regarding comfort come from drivers over age 40;
- Women, overweight, and short drivers experience more problems with comfort/convenience;
- The most important convenience-related issues were:
  - Location and accessibility of buckle;
  - Levels of retraction force;
  - Perceptiveness to webbing extraction;
  - Susceptibility of webbing to tangling and twisting;
  - Belt buckle is too far back;
  - Belt trapped in door;
  - Awkward negotiating around clothes;
  - Belt twisting when getting it, when it retracts, and when adjusting it;
  - Belt locking up unexpectedly when leaning forward and when pulling belt;
  - Reaching for and gripping the belt buckle.

## Cognitive/Personal

As mentioned previously, opinions about the type of signal, signal delivery method, and signal recipient (driver-driver; driver-passenger; and passenger-passenger) were examined separately for each of the nonuse classification groups of respondents. According to our survey, people who cite cognitive/personal reasons (usually forgetting) account for approximately 23 percent of part-time safety belt users nationwide.

**Figure 3: System Signal Preferences as a Driver for an Unbuckled Passenger, Cognitive/Personal Group**

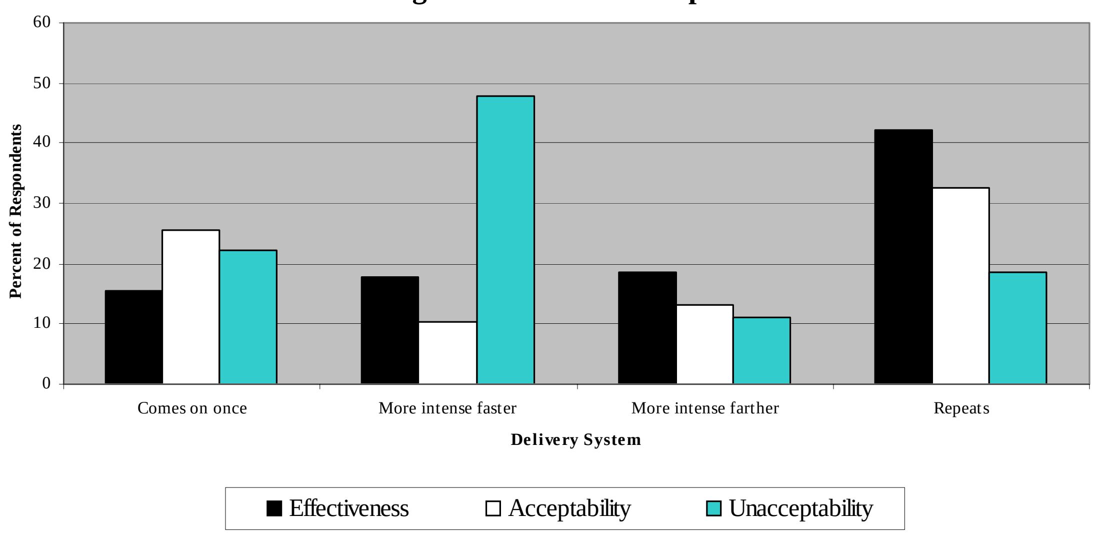



*Type of Signal, Driver-Driver:* Figure 2 shows the percent of cognitive/personal respondents who rated each type of signal on effectiveness, acceptability, and unacceptability as a driver. Unacceptability includes responses to the question: What signals would you definitely not want in your car? As can be seen in Figure 2, the voice message and buzzer scored the highest on perceived effectiveness. The voice message, flashing light, and buzzer also scored high on acceptability. The voice message, flashing light, and chime all scored low on unacceptability.

*Type of Signal, Driver-Passenger:* Figure 3 shows the percent of cognitive/personal respondents who rated each type of signal on their preference, acceptability, and unacceptability for a driver to be reminded that a *passenger* is not using a safety belt. Effectiveness in getting the passenger to buckle-up was not asked about for this situation because a respondent could not be expected to accurately predict the behavior of another vehicle occupant. As can be seen in Figure 3, the voice message, flashing light, and buzzer were selected most often as the preferred signal. The flashing light, voice message, and buzzer were also frequently cited as acceptable signals. The seat vibrator and buzzer were selected most frequently as unacceptable to drivers.

*Type of Signal, Passenger-Passenger:* The percentages of cognitive/personal respondents who selected each type of signal as the most effective for getting them to use a safety belt while they were

**Figure 4: System Signal Delivery Preferences Cognitive/Personal Group**



traveling in a vehicle as a *passenger* were the following: voice (24.7%); buzzer (22.1%); seat vibrator (15.6%); chime (12.8%); and flashing light (12.0%). We only asked about effectiveness, because passengers are not necessarily the owners of the vehicle in which they are traveling so acceptability/ unacceptability is not relevant.

*Type of Signal Deliver, All Types of Systems:* Figure 4 shows the percent of cognitive/personal respondents who rated each signal delivery method on effectiveness, acceptability, and unacceptability. The survey did not explore these questions as a function of seating position. As seen in Figure 4, repeating at a constant interval was the most frequently selected delivery system. Repeating, and a system that comes on once, were judged as the most acceptable overall. The most unacceptable system was one that became more intense the faster the vehicle travels.

**Low-Risk**

According to our survey, people who cite low risk as the reason for part-time belt use account for approximately 39 percent of part-time safety belt users nationwide. As with the cognitive/personal group, three system features were investigated in the survey: the signal type; the way in which the signal was delivered; and who received the signal. We also investigated, to some extent, acceptability and effectiveness of these features for the driver when he or she is not belted (driver-driver), for the driver when a passenger is not belted (driver-passenger); and for the passenger when he or she is not belted (passenger-passenger).

*Type of Signal, Driver-Driver:* Figure 5 shows the percent of low-risk-based respondents who rated each type of signal on effectiveness, acceptability, and unacceptability as a driver. As can be seen in Figure 5, the voice message and buzzer were selected most often as effective signals. The seat vibrator, chime, and voice message were found to be the least acceptable signals. The seat vibrator was selected by nearly half of this group as unacceptable, while nearly 25 percent thought the buzzer was unacceptable.

*Type of Signal, Driver-Passenger***:** The percentages of low-risk-based respondents who rated each type of signal on acceptability as a driver to be told that a passenger was unbelted were the following: flashing light (40.9%); buzzer (16.3%); voice (11.5%); chime (10.9%); and seat vibrator (2.1%).

*Type of Signal, Passenger-Passenger:* The percentages of low-risk-based respondents who selected each type of signal as the most effective for getting them to use a safety belt while they were traveling in a vehicle as a passenger were the following: seat vibrator (24.7%); buzzer (24.5%); voice (15.6%); flashing light (11.9%); and chime (9.5%). We only asked about effectiveness, because passengers are not necessarily the owners of the vehicle in which they are traveling; therefore acceptability is not an issue

*Type of Signal Deliver, All Types of Systems:* Figure 6 shows the percent of low-risk based

**Figure 5: System Signal Preferences as a Driver**
**Low Risk Group**

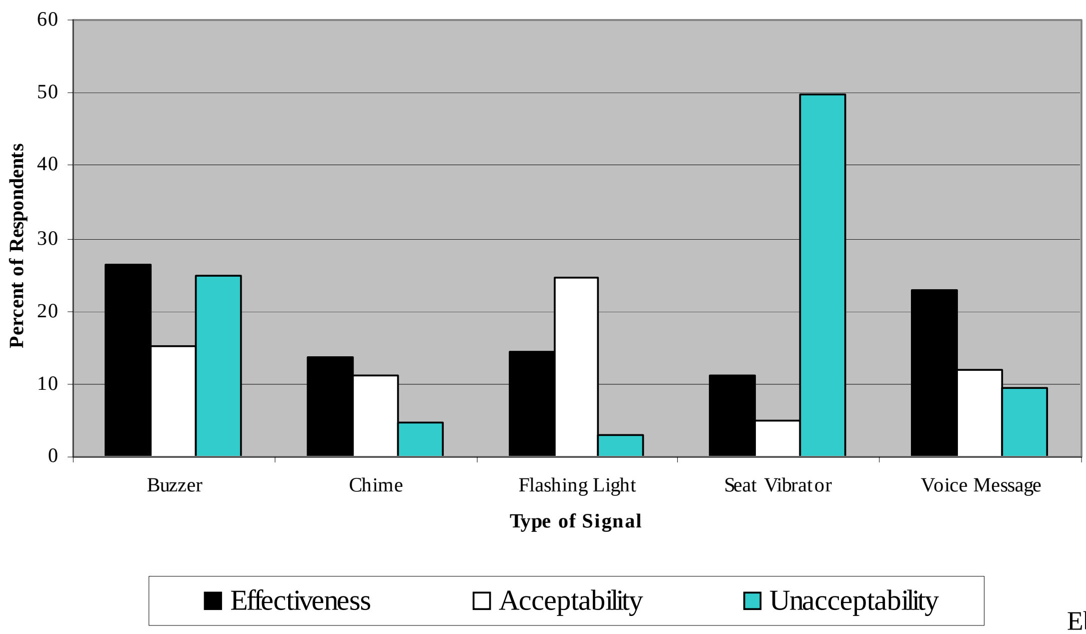
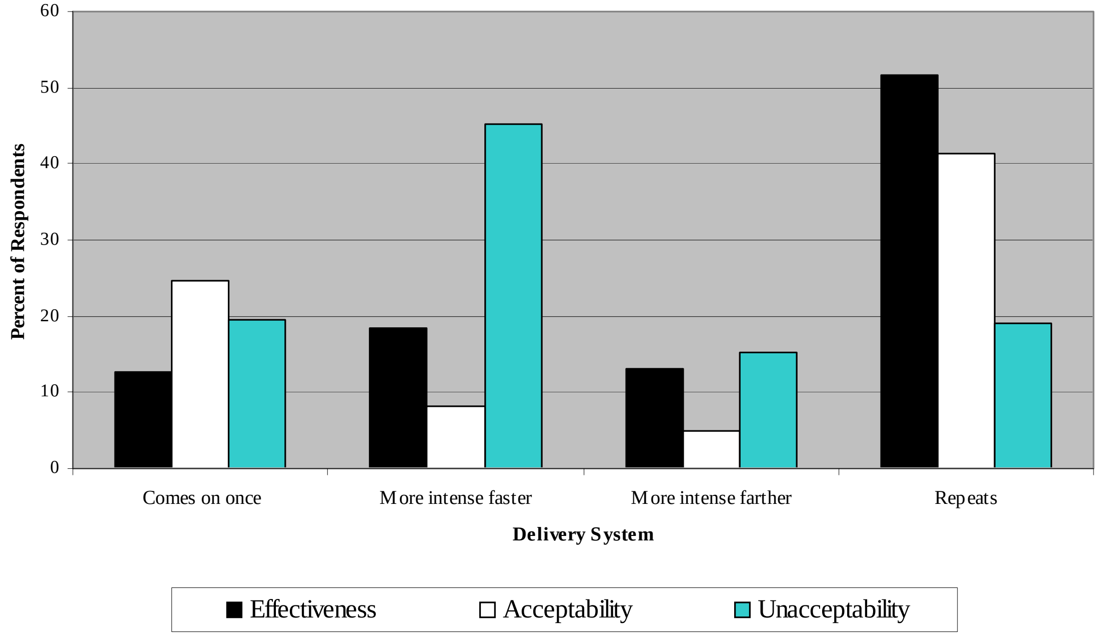


**Figure 6: System Signal Delivery Preferences**
**Low Risk Group**




respondents who selected each method for signal delivery on effectiveness, acceptability, and unacceptability. The survey did not explore this question as a function of seating position. As seen in Figure 6, repeating a signal at a constant interval was the most frequently selected delivery system for effectiveness, followed distantly by a signal that becomes more intense the faster the vehicle moves. The two least acceptable signal delivery methods were one in which the signal gets more intense the farther the vehicle travels and one in which the signal gets more intense the faster the vehicle travels. By far, the most unacceptable delivery method was one that gets more intense the faster the vehicle travels.

**Interlock Systems**

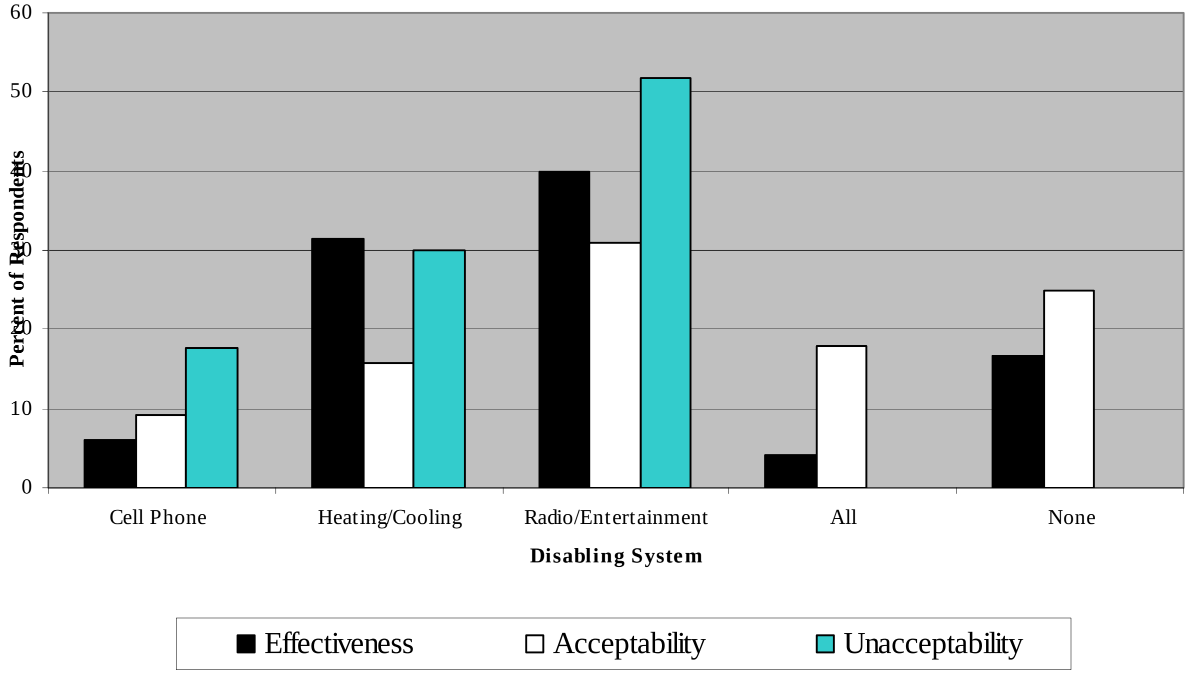
We investigated only interlocks that link to some vehicle feature other than the ignition. If a vehicle has an ignition interlock system, then no other system is necessary. The survey only considered interlock systems that would disable some system operating in the vehicle if anyone in the vehicle was not using a safety belt. Figure 7 shows the percent of respondents who selected each system to be interlocked with safety belt nonuse on effectiveness, acceptability, and unacceptability for all respondents in the survey. The survey clearly showed that disabling the radio/entertainment system was most often judged to be effective for promoting belt use and the most unacceptable system to have in the vehicle. Disabling the heating/cooling system was also judged to be fairly effective and unacceptable.

***Focus Groups***

Complete results of the focus groups, including illustrative quotes can be found elsewhere (Eby et al., 2004). Here we summarize the main findings.

- The main reasons cited for using a safety belt were: safety, Michigan's belt law, setting example for children in car, and belt use being a habit.
- The main reasons cited for not using a safety belt were: discomfort and inconvenience, lack of habit/forgetting, just driving short distance, and low perceived crash risk.
- The most commonly reported reasons for discomfort were: the safety belt cutting into neck, belt locking up or too tight across chest or body, roughness of belt material, tendency to wrinkle clothing, difficulty reaching buckle, and twisting of the belt.
- The following ideas for making belts more comfortable were cited: make belt out of softer material or soften belt edges and add padding to belt to cushion neck and shoulder.
- Nonuse of belts tends to be a deliberate decision rather than simply forgetting. The times when respondents were less likely to use belts were: short trips, a lack of police presence, lower

**Figure 7: Disabling System Preferences**
**All Respondents**




speeds, being in a hurry, and traveling in someone else's car or as a passenger.

- Responses about the point in the driving sequence when participants usually buckle indicate:
  - About half buckle up before starting to drive.
  - About half wait until they are actually driving to put on belt (half of this group wait until they are on patrolled roads).
  - Responses vary considerably across individuals and subgroups.
  - Participants buckle up earlier with passengers present, where there is police presence, on long trips or in unfamiliar areas, in public places with other cars, in inclement weather, and at night.
- Reactions to current US requirement (Level 1 of sample reminder system) were:
  - For most, it works only somewhat well or not at all well to get them to buckle up because of signal's short duration, ease with which it can be ignored, and low level of annoyance.
  - For majority, it is acceptable or very acceptable to have in their car.
- Reactions to Level 2 sound signals were:
  - For each signal - male voice, female voice, buzzer, and beeping signal – a majority thought it would work only somewhat well or not at all well.
  - There was a wide range of individual reactions to signals; similar reasons were often given for both liking and not liking signals.
  - The buzzer was reported to be least acceptable signal, with people voicing strong negative views.
  - The beeping signal was somewhat more acceptable than a male or female voice.
  - Acceptability was often linked to annoyance – the more annoying, the less acceptable.
  - For many, acceptability and effectiveness were inversely linked – the more acceptable, the less effective, and vice versa.
- Reactions to Level 3 sound signals were:
  - For most, the buzzer would work well or very well because of high level of annoyance associated with it.
  - The beeping signal was thought to be less effective because it was easier to ignore.
  - The majority reported that the buzzer would not be at all acceptable and the buzzer was associated with strong negative reactions.
  - The beeping signal was more acceptable than buzzer but was still thought to be only somewhat or not at all acceptable by the majority of participants.
- Reactions to a system that would alert the driver about back seat passengers' belt use were:
  - Opinions were mixed, with support generally limited to situation in which children are in the back seat.
  - The preferred signals were a flashing light and lighted diagram on dashboard to identify seating positions of unbuckled passengers.

- Reactions to a system that would alert back seat passengers directly about their own belt use were:
  - Opinions were mixed with the strongest support from the oldest age group.
  - There was a preference for the driver to remind passengers rather than to have a signal or to have diagram visible to passengers that shows the seating position of unbuckled passenger.
- Reactions to radio or entertainment center interlock system were:
  - There was general opposition to this system that was sometimes strong, with many finding the system unacceptable.
  - Concern was expressed that system would only work if people listened to the radio.
  - The oldest age group was somewhat more supportive of the system.
- Reactions to an ignition interlock system were:
  - Reactions were generally negative with many people stating that the system goes too far.
  - Concerns were expressed about how the system would work in emergency situations when driver might need to move quickly or in circumstances when belt could not be worn by someone in car.
  - Somewhat more favorable views were expressed from oldest age group, especially those who lived in an urban setting.

## DISCUSSION AND CONCLUSIONS

This section contains a synthesis of the results from the literature review, telephone survey, and focus groups in order to provide guidelines for the development of an optimal in-vehicle safety belt promotion system.

### *Principles for Optimal System Design*

Based upon previous work (Turnbell et al., 1996) and our own expertise, we derived seven principles for the development of an optimal safety belt reminder system:

1. The fulltime safety belt user should not notice the system.
2. It should be more difficult and cumbersome to cheat on the system than to use the safety belt.
3. Permanent disconnection of the system should be difficult.
4. The system should be reliable and have a long life.
5. Crash and injury risk should not be increased as a result of the system.
6. System design should be based on what is known about the effectiveness and acceptability of system types and elements.
7. System design should be compatible with the manufacturer's intended purpose/goals for the system.

### *Different Systems For Different Belt Users*

Our results showed that the part-time belt users in the US fall into three broad, distinct categories when the reasons for part-time nonuse are considered: comfort/convenience, cognitive/personal, and low perceived risk. Full-time users, by virtue of their belt use pattern, form a fourth distinct group. Full-time nonusers, who are willing to face citations and higher injury levels in the event of a crash, form a distinct fifth belt use group. Thus, safety belt use behavior among people in different categories is motivated by different factors. We conclude, therefore, that optimal in-vehicle belt promotion technologies should target people in the different categories using different systems features and/or systems.

### *Level of Intrusiveness*

In a recent publication by the Transportation Research Board (TRB, 2003), safety belt promotion technologies were described as varying along an intrusiveness dimension, with reminder systems at the low end of the intrusiveness scale and interlock systems at the high end of the scale. This concept,

**Figure 8: Safety belt use groups aligned in order of the relative level of system intrusiveness that is most likely to change behavior.**

| ***Safety Belt Use Group*** | Part-time user: comfort/convenience | Full-time user | Part-time user: cognitive/personal | Part-time user: low perceived risk | Full-time nonuser |
|---|---|---|---|---|---|
| | ***Level of Intrusiveness*** | Low | | | High |

combined with the conclusions that different users should be targeted with different features and/or systems, led us to the conclusion that the optimal in-vehicle technology should be adaptive in response to the type of belt user. A similar conclusion has been drawn by other researchers (TRB, 2003; Fildes, Fitzharris, Koppel, & Vulcan, 2002).

The conclusion that different belt use groups should be targeted with different features and/or systems and that the level of intrusiveness should be different depending upon the group, led to the development of Figure 8. The figure shows a continuum of intrusiveness, with low intrusiveness on the left and high on the right. We have placed each belt use group along the continuum, based on how we thought the intrusiveness of the system and/or features designed for each group would fall relative to each other. Note that the comfort/convenience part-time user group is not placed along the continuum. The most effective countermeasure for promoting belt use among this group is proper human factors and ergonomics research to enhance the comfort and convenience of safety belts. Low on the continuum are the full-time users, while high on the continuum are the full-time nonusers. In the middle part of the continuum, we have first placed the cognitive/personal part-time user group, followed by the low-perceived-risk group. Thus, we propose that cognitive/personal part-time users need a less intrusive system for the effective promotion of belt use than those in the low perceived risk group.

***Effectiveness versus Acceptability***

As previously discussed, the main thrust of the current research was to qualitatively determine which signals, signal presentation methods, and systems would be most likely to get a user to buckle up and would be acceptable to have in a vehicle. Effectiveness and acceptability, however, can be at odds with one another in belt promotion systems; that is, a highly intrusive system would be so unacceptable that even though the driver would be more likely use his or her belt to stop the annoyance, he or she would not want the system in the vehicle.

In order to maximize both effectiveness and acceptability, we developed effectiveness and acceptance criteria for each system feature and/or system to be targeted at each belt use group. These criteria are shown in Figure 9. Based upon Principle 1 for optimal system design, full time users, or those who use their belt at the start of trip, should not notice the system; that is, the system goal is that it is invisible to the full-time user. For the part-time belt users for cognitive/personal reasons, a more intrusive system is needed. The goals of this system are to maximize both user acceptance and effectiveness. Such a system corresponds to what is currently called a *safety belt reminder system*. The part-time users who cite low perceived risk as the reason for nonuse, do not need reminding, but instead need a system that provides a great enough annoyance to get people to use their belt. For lack of a better term, we have called this type of system an *annoyance system*. Because the system would be designed to be unpleasant, the system goal here is to maximize effectiveness and minimize acceptance. If this system was acceptable, then it would not be annoying enough to change behavior. Finally, we have the hard-core full-time nonusers. Despite the fact that safety belt nonuse can result in a citation and greater injury in the event of a crash, these people have made the conscious decision to not buckle up. Therefore, we believe that only the most intrusive system, an

**Figure 9: Types of systems and system goals necessary for effective and acceptable in-vehicle safety belt promotion technology.**

| ***Intrusiveness*** → | | | | |
|---|---|---|---|---|
| ***Safety Belt Use Group*** | **Full-time user** | **Part-time user: cognitive/personal** | **Part-time user: low perceived risk** | **Full-time nonuser** |
| ***System Goals*** | **System invisible to driver** | **Effectiveness and user acceptability are maximized** | **Effectiveness is maximized; acceptability is minimized** | **Acceptability is minimized** |
| ***Type of System Engaged*** | **No system engaged** | **Reminder system** | **Annoyance system** | **Interlock system** |

*interlock system,* would be effective in getting these people to use a safety belt. As such, the system goal is simply to minimize acceptability.

***Signal Type and Presentation Method***

Following the framework depicted in Figure 9, the next step in developing an optimal in-vehicle belt promotion system was to determine which signals and signal presentation methods best met the system goals for each belt use group. According to the first system design principle discussed previously, if a driver uses his or her belt, the in-vehicle belt promotion technology should be invisible. Therefore, there should be no signal presented to this group. This recommendation suggests that the current 4-8 second signal that is required in US vehicles be removed.

For the cognitive/personal part-time belt use group, our survey suggested that the signals that maximized effectiveness and acceptability were a flashing light and a voice message. During the focus group discussions, however, where actual voice messages were presented, it was clear that there were strong preferences for certain voices and strong dislikes for others, and these preferences were not consistent. Having a single voice message, therefore, would be unacceptable for many users and would violate an important goal of the system for this belt use group. Many focus group participants suggested that they be allowed to input or select the voice used in this system. Since acceptance is an important criteria for this group, we extend this idea, and propose that the signal, whether it is a specific voice, light, buzzer, or chime, be selectable by the driver. The presentation method for the signal, on the other hand, must still maintain a moderate level of intrusiveness to be effective. An optimal delivery method would be selected most often by the cognitive/personal respondents as effective and acceptable, and least often as unacceptable. As seen in Figure 8, repeating at a constant interval scored high on both acceptability and effectiveness. Thus, based upon these results, we recommend that the signal delivery method for reminder systems should be one that repeats at a constant interval.

Moving along the intrusiveness continuum, the next system is the annoyance system targeted at those drivers who are part-time belt users due to low perceived risk. An optimal signal and delivery method for this group should optimize effectiveness and minimize acceptability. As shown in Figure 9, the buzzer scored fairly high on both effectiveness and unacceptability. The seat vibrator scored quite high on unacceptability but quite low on effectiveness. Based upon these survey results, the buzzer seems to be the best annoyance signal for getting a driver to buckle-up. Based on the finding in Figure 8, a signal that gets more intense the faster the vehicle travels scored high on both effectiveness and unacceptability. We conclude, therefore, that this would be the best signal delivery method for getting

**Figure 10: Types of systems, system goals, signal, and signal presentation methods necessary for effective and acceptable in-vehicle safety belt promotion technology**

| ***Intrusiveness*** → | | | | |
|---|---|---|---|---|
| ***Safety Belt Use Group*** | **Full-time user** | **Part-time user: cognitive/personal** | **Part-time user: low perceived risk** | **Full-time nonuser** |
| ***System Goals*** | **System invisible to driver** | **Effectiveness and user acceptability are maximized** | **Effectiveness is maximized; acceptability is minimized** | **Acceptability is minimized** |
| ***Type of System Engaged*** | **No system engaged** | **Reminder system** | **Annoyance system** | **Interlock system** |
| ***System Signal Type*** | **No signal** | **User selected** | **Buzzer** | **Shut off entertainment system** |
| ***Signal Presentation Method*** | **No signal** | **Repeats at a constant interval** | **Intensity increases the faster the vehicle moves** | **A warning signal prior to interlock** |

the low-risk-based part-time belt user to buckle up. Note that we did not describe the characteristics of how the intensity of the signal changes. There are three options that are open for further research: increasing frequency (decreasing the inter-signal-interval); increasing volume, and increasing pitch.

The final group to target are the full-time nonusers. This group is targeted with the most intrusive system, the interlock. The system goals for the interlock, are simply to maximize unacceptability—drivers should not like having the system engage. Here we do not consider effectiveness, because these drivers will either buckle up or go to the extreme measure of disconnecting the system. Figure 7 shows that the most unacceptable vehicle system to interlock with belt use is the radio/entertainment system. This is also the system that our respondents thought would be most effective. One must be careful, however, to design this system so that the driver is not surprised and potentially distracted trying to figure out why the entertainment system is not operating. Such a situation could increase the driver's chance of crashing, violating system design Principle 5. Therefore, we propose that the optimal delivery system provide a warning signal (not determined in this study) prior to engaging the interlock, so that the driver is aware that the interlock has turned off the entertainment system. The recommended system features for all safety belt user groups are summarized in Figure 10.

***An Integrated and Adaptive Reminder System***

The final issue in the development of an optimal in-vehicle safety belt promotion system, is how to integrate the various systems we have discussed. We propose the adaptive system depicted in Figure 11. The figure depicts an adaptive system that changes its characteristics as the trip proceeds either in time, distance, vehicle operation, or some other metric. The figure also shows for each period of the trip, the safety belt nonuse group that is targeted by the system, that group's primary reasons for nonuse of safety belts, the system that is activated, and the important characteristics of the countermeasure. Once a trip begins, the system assumes that the driver is a full-time user and does nothing. Thus, if the driver uses his or her safety belt, then the system is invisible to them. If, however, belts are not used within some period of time or distance traveled (or other metric), then the system assumes that the unbelted driver has forgotten to use his or her safety belt. At this point, the reminder system is activated. As more time passes, or as a greater distance is traveled, if the driver still does not use his or her

**Figure 11: Framework for an adaptive, integrated driver-driver in-vehicle belt promotion system**

| ***Example Metrics*** | Car not started<br>0 seconds<br>Start of trip | Car started, not in gear<br>< 10 mph;<br>4- 8 seconds | Car starts moving<br>11- 25 mph<br>2- 3 minutes | Car on patrolled roadways<br>> 25 mph<br>5 minutes |
|---|---|---|---|---|
| ***Safety Belt Use Group*** | Full-time user | Part-time user: cognitive/personal | Part-time user: low perceived risk | Full-time nonuser |
| ***System Goals*** | System invisible to driver | Effectiveness and user acceptability are maximized | Effectiveness is minimized; acceptability is minimized | Acceptability is minimized |
| ***Type of System Engaged*** | No system engaged | Reminder system | Annoyance system | Interlock system |
| ***System Signal Type*** | No signal | User selected | Buzzer | Shut off entertainment system |
| ***Signal Presentation Method*** | No signal | Repeats at a constant interval | Intensity increases the faster the vehicle moves | A warning signal prior to interlock |

safety belt, then the system assumes that the driver has chosen not to use a belt because of a low perceived risk of a crash or citation. At this point, the annoyance system is activated. Again, as more time or distance passes without the driver using his or her belt, at some point the system assumes that the driver is a full-time nonuser and an interlock system is activated, shutting off the entertainment system following the warning signal. If at any time during the trip, the buckled driver removes his or her belt, the sequence of events begins again.

*The Choice of a Metric:* The project did not gather definitive information about which metric is optimal or at which point along the metric the various systems should engage. We have provided three examples, based on our best judgment, the literature review, and comments from the focus group participants. In particular, during the focus groups, we discussed when during an average trip people buckle up. We developed the first metric based on how people answered this question. When choosing a metric, it is important to keep in mind the principles of optimal system development, in particular the principle that states that safety should not be compromised. The most appropriate metric or combination of metrics should be the topic of further research.

***Other Reminder System Recommendations***

The previous system design recommendations refer to a system designed to promote driver safety belt use (called driver-driver systems). This project, however, also investigated (in less detail) features of systems to inform the driver that a passenger is not using a safety belt (called driver-passenger systems) and to inform a passenger that he or she is not buckled (called passenger-passenger systems).

*Driver-Passenger Systems*: The intent of this system is to let the driver know that a passenger is not using a safety belt. In most US jurisdictions, adult passengers in a vehicle are responsible for their own belt use and will receive the citation for nonuse. Non-adult passengers, on the other hand, are the responsibility of the driver who can be cited for violating the child passenger safety law, if a non-adult does not use a proper restraint. As such, the goal of a driver-passenger system is to inform the driver of passenger nonuse of belts, so that he or she can require and monitor passenger belt use. Because the driver may not have perceived authority over an adult passenger, we conclude that a driver-passenger system should include the reminder and interlock components, but not the annoyance component of the system described in Figure 11. The signal type indicated for driver-passenger systems in the survey that maximized effectiveness and acceptability was a flashing light on the dashboard. In the focus groups, however, many participants suggested that the driver should be presented with a pictograph that shows the seating positions where passengers are not buckled. Combining these two ideas, we propose that the best signal and signal presentation method for a driver-passenger system is a seating-position pictograph that flashes at a constant interval.

*Passenger-Passenger Systems*: This type of system is designed to let passengers know that they are unbelted and encourages them to use their belt. As with driver-passenger systems, the passenger may be a child or adult. The large majority of focus group participants did not favor such a system, preferring that the driver tell the passenger. Therefore, as with the previous system, the annoyance system component should be omitted from a passenger-passenger system. Survey results showed that respondents thought the most effective signal for the reminder component of a passenger-passenger system would be either a buzzer or a voice message. In the focus groups, however, these signals were strongly opposed in favor of either a flashing light or no signal at all. The survey did not investigate acceptability of various passenger-passenger system components, but the focus group results suggested that the buzzer or voice would not be well received by vehicle owners. We propose, therefore, that the best signal and signal presentation method for a passenger-passenger system is a light or “unbelted” pictograph that flashes at a constant interval.

***A Fully Integrated System***

We have discussed three potential systems to promote safety belt use. These systems, however, would be most effective if they were integrated. Figure 12, shows the framework for a fully integrated system. This figure shows the sequence of signals, how they should be presented, and to whom, as the trip progresses. If the driver puts on his or her belt, then the sequence for the driver stops. If the passenger puts on his or her belt, then the sequence for the passenger stops. If either the driver or passenger unbuckles after having used the belt, the sequence will begin again for the person who unbuckles.

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**Figure 12: Framework for a fully-integrated, adaptive in-vehicle safety belt promotion system**

| | | | | |
|---|---|---|---|---|
| ***Example Metrics*** | Car not started<br>0 seconds<br>Start of trip | Car started, not in gear<br>< 10 mph;<br>4- 8 seconds | Car starts moving<br>11- 25 mph<br>2- 3 minutes | Car on patrolled roadways<br>> 25 mph<br>5 minutes |
| ***Type of System*** | No system engaged | Reminder system | Annoyance system | Interlock system |
| ***Driver*** | No signal | If driver not belted: user-selected signal that repeats at constant interval. If passenger not belted: flashing pictograph showing seat location | If driver not belted: buzzer that increases in intensity the faster the vehicle moves. If passenger not belted: flashing pictograph showing seat location | If driver not belted: a warning signal, then entertainment interlock. If passenger not belted: flashing pictograph showing seat location |
| ***Passenger*** | No signal | Light or "unbelted" pictograph" that flashes at a constant interval | | A warning signal followed by entertainment system interlock. |

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